(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 January 2002 (31.01.2002)

PCT

(10) International Publication Number
WO 02/09407 A2

(51) International Patent Classification[7]: H04M 11/00

(21) International Application Number: PCT/US01/22019

(22) International Filing Date: 13 July 2001 (13.07.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/620,503 20 July 2000 (20.07.2000) US

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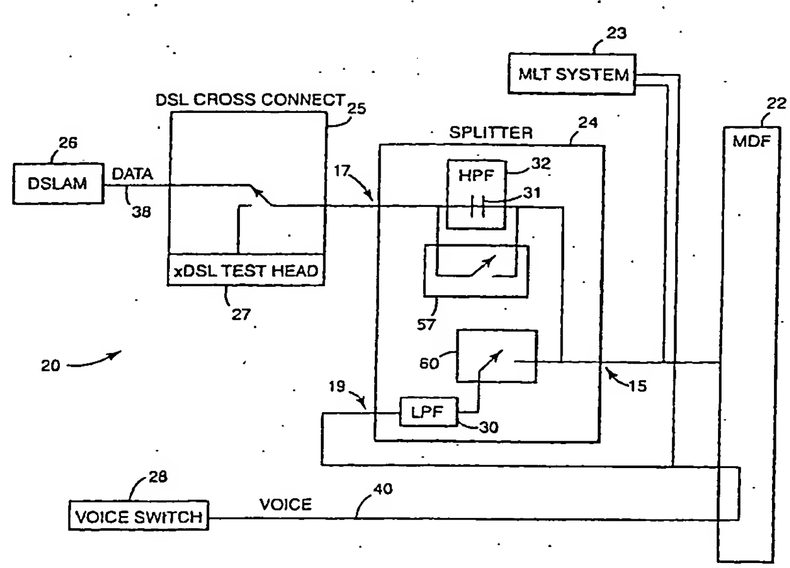
(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: VOICE/DATA SIGNAL SPLITTER EMPLOYING CONTROLLABLE BYPASS APPARATUS AND METHOD.



(57) Abstract: An apparatus and method for bypassing circuitry of a voice/data splitting unit connectable to a communications connection involves a voice line and a data line of the communications connection. The bypass method involves bypassing a DC and/or low frequency filtering element of the splitter unit coupled to the data line and decoupling the voice line from the splitter unit during non-usage of the voice line so as to provide full frequency spectrum test access to the voice and data lines. Testing one or both of the voice and data lines during non-usage of the voice line and after completion of the bypassing operation may be performed. The bypass method further involves recoupling the voice line to the splitter unit in response to usage of the voice line.

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VOICE/DATA SIGNAL SPLITTER EMPLOYING CONTROLLABLE BYPASS APPARATUS AND METHOD

FIELD OF THE INVENTION

The present invention relates generally to telecommunications equipment and, more particularly, to an apparatus and method for providing full frequency spectrum test access to communication lines employing voice and data signal splitting devices.

BACKGROUND OF THE INVENTION

Various techniques have been developed within the telecommunications industry for transmitting voice and data signals to residences and businesses over existing copper telephone lines. A telecommunication service which utilizes an existing copper infrastructure is often referred to as a Plain Old Telephone Service (POTS). A telecommunications system that provides for the transmission of mixed voice/data signals utilizes a device that separates mixed voice/data signals into a lower frequency voice signal and a higher frequency data signal.

Such devices are commonly referred to as POTS splitters. A typical POTS splitter is implemented as a passive device, meaning that the POTS splitter operates without the need for power. A common POTS splitter design employs both a lowpass filter and a highpass filter. The lowpass filter is used to extract the voice signal from the mixed voice/data signal. The highpass filter is used to extract the data signal from the mixed voice/data signal.

An ADSL (Asymmetrical Digital Subscriber Line) service, for

example, provides for the concurrent transmission of voice and data signals over conventional copper connections. A significant advantage of an ADSL service concerns the capability to provide both voice and data to a home or business using a single telephone connection. Such ADSL services require a POTS splitter to extract the respective voice and data signals from the mixed voice/data signal transmitted over the single telephone connection.

Testing of mixed voice/data communications lines in which a POTS splitter is introduced has proved challenging, particularly where supporting lifeline POTS service is a requirement. Moreover, the filtering elements and impedances associated with a typical POTS splitter as deployed prevents or significantly complicates the ability to perform full frequency spectrum testing of a selected communications line or loop.

There exists a need in the telecommunications industry for an improved POTS splitter device that provides for filtering of voice and data signal content of a mixed or composite voice/data signal. There exists a further need for a POTS splitter device that provides for full frequency spectrum testing of a communications line or loop that passes therethrough. The present invention fulfills these and other needs.

SUMMARY OF THE INVENTION

The present invention is generally directed to an apparatus and method for splitting a first band of signal frequencies and a second band of signal frequencies of a multiband signal transmitted over a communications connection comprising a first signal line and a second signal line. The present invention is further directed to a controllable bypass apparatus and method which provides for full frequency spectrum test access to communication lines employing multiband signal splitting devices.

According to an embodiment of the present invention, a signal splitter apparatus having a controllable bypass capability includes a splitter unit having a voice/data port, a first port connectable to a first signal line, and a second port connectable to a second signal line. The splitter unit further includes a first filtering element coupled to the first signal line and a second filtering element coupled to the second signal line, such that the second filtering element degrades at least a portion of the frequency spectrum associated with the second band of signal frequencies. In a particular embodiment, the second filtering element includes a DC and/or low frequency degrading element and the first filtering element includes a lowpass filter element.

A bypass device is coupled to the first signal line and the second signal line. According to an embodiment of the present invention, the bypass device includes a first bypass circuit for controllably decoupling the first signal line with respect to a first signal line location between the voice/data port of the splitter unit and the first filtering element. The bypass device further includes a second bypass circuit for controllably bypassing the second filtering element with respect to the second signal line.

According to another embodiment, the bypass device includes a first bypass circuit for controllably decoupling and recoupling the first signal line with respect to a first signal line location between the voice/data port of the splitter unit and the first filtering element. The bypass device further

includes a second bypass circuit for controllably bypassing and recoupling the second filtering element with respect to the second signal line.

The bypass device typically includes a controller coupled to the respective first and second bypass circuits. The controller controls the first and second bypass circuits in response to usage of the first signal line. The bypass device may further include a sensor that senses usage of the first signal line. The sensor may include one or both of a current detector and/or a voltage detector. The sensor may employ other types of detectors, such as a magnetic or electromagnetic detector (e.g., Hall-effect device), an optical detector, or other type of detector that senses usage of the first signal line.

In another embodiment of the present invention, the bypass device includes a controller coupled to a first signal line sensor and respective first and second bypass circuits. The controller controls the first and second bypass circuits in response to usage of the first signal line as determined by the sensor. For example, in response to non-usage of the first signal line as detected by the sensor, the controller controls bypassing of the second filtering element coupled to the second signal line and decoupling of the first signal line at a first signal line location between the voice/data port of the splitter unit and the first filtering element. In response to usage of the first signal line as detected by the sensor, the controller controls recoupling of the second filtering element to the second signal line and recoupling of the first signal line to the first signal line location between the voice/data port of the splitter unit and the first filtering element.

The second bypass circuit may include a controllable relay coupled around the second filtering element coupled to the second signal line. The first bypass circuit may include a controllable relay that controllably decouples and recouples the first signal line with respect to a first signal line location between the voice/data port of the splitter unit and the first filtering element.

According to a further embodiment, the bypass device includes a

timing circuit that determines a duration of time during which the second bypass circuit bypasses the second filtering element coupled to the second signal line. The timing circuit also determines a duration of time during which the first bypass circuit decouples the first signal line from the first signal line location between the voice/data port of the splitter unit and the first filtering element. The time duration of first and second bypass circuit operability may be of the same or different duration.

The bypass device may further include a power circuit for powering the first and second bypass circuits. The power circuit may derive power from a source external to the splitter unit or the bypass device. For example, the power circuit may derive power from a line testing device. According to another embodiment, the power circuit includes a timing circuit. The timing circuit determines a duration of time during which the second bypass circuit bypasses the second filtering element coupled to the second signal line and during which the first bypass circuit decouples the first signal line from the first signal line location between the voice/data port of the splitter unit and the first filtering element.

In accordance with yet another embodiment of the present invention, a method of bypassing circuitry of a voice/data splitting unit connectable to a communications connection involves a voice line and a data line of the communications connection. The bypass method involves bypassing a DC and/or low frequency filtering element of the splitter unit coupled to the data line and decoupling the voice line from the splitter unit during non-usage of the voice line so as to provide full frequency spectrum test access to the voice and data lines. Testing one or both of the voice and data lines during non-usage of the voice line and after completion of the bypassing operation may be performed. The bypass method further involves recoupling the voice line to the splitter unit in response to usage of the voice line.

The bypass methodology may further involve interrupting data signal transmission on the data line. A test signal may be used to detect a condition or characteristic of the data line and/or at least a portion of the

voice line (e.g., detecting an impairment to the data or voice line, determining line lengths using signal reflection, or detecting the presence of undesirable load coils, impedances, and capacitances). Further, the voice line may be sensed to determine usage and non-usage of the voice line. Sensing the voice line may involve sensing a current or a voltage developed on the voice line. The voice line is recoupled to the splitter unit in response to usage of the voice line or expiration of a predetermined duration of time.

Bypassing the DC and/or low frequency filtering element may further involve establishing a shunt or other connection around the DC and/or low frequency filtering element, such as by activating a controllable relay that establishes a shunt around the DC and/or low frequency filtering element.

Decoupling the voice line may further involve removing impedances associated with the splitter unit and/or downstream voice line circuitry from the voice line. Decoupling the voice line may also involve activating a controllable relay to decouple the voice line from the splitter unit. Recoupling the voice line may involve activating a controllable relay to recouple the voice line with the splitter unit.

The bypass method may further involve deriving power from a power source prior to initiating the bypassing and recoupling operations. The bypass method may also involve removing the power from the power source in response to initiating the bypassing and recoupling operations, such that the voice line is recoupled to the splitter unit and the DC and/or low frequency filtering element of the splitter unit is recoupled to the data line in response to depletion of the derived power to a preestablished threshold.

According to another embodiment of the present invention, an apparatus is provided for splitting voice and data signal content of a mixed voice/data signal transmitted over a communications connection comprising a voice line and a data line. The apparatus includes a splitter unit having a voice/data port of the input, a voice port connectable to the voice line, and a data port connectable to the data line. The splitter unit further includes a DC

and/or low frequency filtering element coupled to the data line, and a lowpass filter coupled to the voice line.

A bypass device is coupled to the voice line and the data line. The bypass device, according to this embodiment, includes a data line bypass circuit for controllably bypassing and recoupling the DC and/or low frequency filtering element with respect to the data line. The bypass device also includes a voice line bypass circuit for controllably decoupling and recoupling the voice line with respect to a voice line location between the voice/data port of the splitter unit and the lowpass filter.

The bypass device typically includes a controller coupled to the respective data and voice line bypass circuits. The controller controls the data and voice line bypass circuits in response to usage of the voice line. The bypass device may also include a voice line sensor that senses usage of the voice line, such as a voice line sensor that includes one or both of a current detector and/or a voltage detector.

The bypass device may further include a controller coupled to a voice line sensor and the respective data and voice line bypass circuits. The controller controls the data and voice line bypass circuits in response to usage of the voice line as determined by the voice line sensor.

For example, the bypass device may include a controller coupled to a voice line sensor and the respective data and voice line bypass circuits. In response to non-usage of the voice line as detected by the voice line sensor, the controller controls bypassing of the DC and/or low frequency filtering element coupled to the data line and decoupling of the voice line at a voice line location between the voice/data port of the splitter unit and the lowpass filter. In response to usage of the voice line as detected by the voice line sensor, the controller controls recoupling of the DC and/or low frequency filtering element to the data line and recoupling of the voice line to the voice line location between the voice/data port of the splitter unit and the lowpass filter.

The data line bypass circuit may include a controllable relay coupled around the DC and/or low frequency filtering element coupled to the data line. The voice line bypass circuit may include a controllable relay that controllably decouples and recouples the voice line to a voice line location between the voice/data port of the splitter unit and the lowpass filter.

The bypass device may further include a timing circuit that determines a duration of time during which the data line bypass circuit bypasses the DC and/or low frequency filtering element coupled to the data line and during which the voice line bypass circuit decouples the voice line from a voice line location between the voice/data port of the splitter unit and the lowpass filter. The bypass device may also include a power circuit for powering the data and voice line bypass circuits. The power circuit may derive power from a source external to the splitter unit or the bypass device, such as from a line testing device or cross-connect unit.

The power circuit may include a timing circuit. The timing circuit determines a duration of time during which the data line bypass circuit bypasses the DC and/or low frequency filtering element coupled to the data line and during which the voice line bypass circuit decouples the voice line from the voice line location between the voice/data port of the splitter unit and the lowpass filter.

According to a further embodiment of the present invention, a splitter unit includes a relay coupled between the bypass device and a power source. The relay is controllable to decouple the power source from the bypass device and to remove impedances associated with the bypass device from a test path.

The bypass device, in one embodiment, is integral with the splitter unit. In another embodiment, the bypass device is external to the splitter unit. The bypass device may be responsive to a signal received from a device external to the splitter unit or the bypass device. For example, the bypass device may be responsive to a signal received from a tester unit or a remotely located system. The signal may, for example, activate or

deactivate the bypass device.

In accordance with yet another embodiment, a method of the present invention provides for splitting a first band of signal frequencies and a second band of signal frequencies of a multiband signal transmitted over a communications connection comprising a first signal line and a second signal line. During non-usage of the first signal line, DC and/or low frequency filtering of the second signal line is disabled, and the first signal line is decoupled from line impedances so as to provide full frequency spectrum test access to the first and second signal lines. The first signal line is recoupled to the line impendances in response to usage of the first line.

A splitting methodology according to this embodiment may further involve interrupting signal transmission on the second signal line and using a test signal to detect a condition or characteristic of the second signal line and/or at least a portion of the first signal line. Sensing the first signal line may be effected to determine usage and non-usage of the first signal line. The first signal line may be recoupled to the line impedances in response to usage of the first signal line or expiration of a predetermined duration of time. Power may be derived from a power source prior to initiating the disabling and recoupling operations. Testing of one or both of the first and second signal lines may occur during non-usage of the first signal line and after completion of the disabling operation.

The above summary of the present invention is not intended to describe each embodiment or every implementation of the present invention. Advantages and attainments, together with a more complete understanding of the invention, will become apparent and appreciated by referring to the following detailed description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of telecommunications system components for transmitting a mixed voice/data signal, such as an ADSL signal, and voice and data signals separated therefrom, the system including a voice/data signal splitter unit employing controllable bypass circuitry that provides for full frequency spectrum line testing in accordance with the principles of the present invention;

Fig. 2 illustrates in flow diagram form various steps involving the controlled bypassing of DC/low frequency filtering elements of a data signal path and controlled bypassing of lowpass voiceband circuitry from a loop under test in accordance with an embodiment of the present invention;

Fig. 3 is an illustration of a splitter unit employing controllable bypass circuitry that provides for full frequency spectrum line testing in accordance with an embodiment of the present invention;

Figs. 4 and 5 illustrate in flow diagram form various steps involving the controlled bypassing of DC/low frequency filtering elements of a data signal path and controlled bypassing of lowpass voiceband circuitry from a loop under test in accordance with another embodiment of the present invention; and

Fig. 6 illustrates an embodiment of a cross-connect unit effectively incorporating a highpass filter which includes a DC blocking capacitor.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail hereinbelow. It is to be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the invention is intended to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS

In the following description of the illustrated embodiments, references are made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration, various embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized, and structural and functional changes may be made without departing from the scope of the present invention.

A splitter unit implemented in accordance an embodiment of the present invention provides several improvements over conventional ADSL/POTS (Asymmetrical Digital Subscriber Line/Plain Old Telephone Service) and ADSL/ISDN (Integrated Services Digital Network) splitter architectures. For example, a splitter unit of the present invention provides users the ability to comply with line sharing requirements (e.g., FCC Ruling #355, November 18, 1999) and wideband Mechanized Loop Testing (MLT) methodologies without the need for manual intrusive tasks being performed by a Central Office (CO) technician.

A significant advantage provided by a splitter unit implemented in accordance with the principles of the present invention concerns the ability to fully support lifeline POTS and lifeline ISDN service requirements. The term "lifeline" as used in this context refers to a level of service in which telephonic or voice connectivity with emergency services (e.g., "911" services) remains undisturbed and uninterruptable by the presence or activity of splitter/bypass circuitry of the present invention.

Another advantage of the present invention concerns a splitter/bypass unit that provides for remote control/access of any frequency band available on the outside plant loop. A relay control and bypass mechanism consistent with the principles of the present invention may be readily implemented in different splitter platforms and topologies. Further, the bypass relay architecture of the present invention is not intended to be limited to ADSL system topologies. Any splitter topology using band

separation techniques may realize the advantages offered by the invention where multiband access is desired. For example, the bypass relay architecture of the present invention may be advantageously implemented in systems supporting VDSL (Very high speed DSL), etc.

A bypass relay design methodology of the present invention provides for the same basic architecture to be used with numerous topologies and, with the use of standard components, allows the designer to implement bypass functionality in a large number of configurations. Moreover, a bypass relay topology and implementation of the present invention is unique in that the bypass circuitry can be isolated from normal central office (CO) power sources and is implementable on a per-channel scale.

Specific problems solved by the bypass circuitry architecture of the present invention include frequency access (e.g., MLT) limitations typically imposed by a conventional splitter topology. In particular, DC blocking capacitors typically disposed in the DSL or high frequency signal path presents a barrier to DC and low frequency line testing. A design methodology of the present invention allows direct metallic access to any point in the system topology, thereby minimizing the manual reconfiguration and testing of metallic pairs, such as is mandated by the November, 1999 FCC line-sharing Ruling #355.

Application of this topology to different densities and transport topologies is readily achievable by judicious selection of physical components. Careful consideration of connectors, printed circuit board (PCB) of flexible substrate material, shielding, when and where necessary, and component layouts allows a topology of the present invention to be used for many specific applications including, but not limited to, xDSL systems.

Conventional splitter connectivity platforms are often implemented using a non-DC blocking capacitor topology. While considered less difficult to design, a significant disadvantage to this approach is that the application of extraneous voltages appear directly at the DSL equipment ports. These

signals, including ringing voltages, can present large inductive surges to sensitive DSL linecards. This condition, as well as several others, can lead to the destruction of sensitive and expensive data handling/communications equipment.

By way of example, a DSL linecard failure in such a non-blocking topology could, with high probability, impose a failure condition on the external POTS loop. Such a failure under a short-circuit condition would likely result in liabilities resulting from a loss of lifeline POTS service. A topology of the present invention provides for the addition of bypass circuitry that guarantees lifeline POTS support would not be adversely affected by such inductive conditions. Multi-Dwelling Units (MDUs), as well as remotely fed optical pedestal implementations, may also benefit from the addition functionality of the present invention.

Referring now to Fig. 1, there is shown a block diagram of various telecommunications system components for bi-directionally transmitting a mixed voice/data signal, such as an ADSL signal, and for separating or splitting voice and data signals from the mixed voice/data signal. The portion of the telecommunications system 20 shown in Fig. 1 includes an MDF (Main Distribution Frame) 22, a POTS (Plain Old Telephone Service) splitter 24 for separating voice and data signals in accordance with the present invention, a DSLAM (Digital Subscriber Line Access Multiplexer) device 26, and a voice switch 28. The system 20 is shown to further include a digital cross connect system 25 coupled between the splitter unit 24 and the DSLAM 26.

During normal operations, a mixed voice/data signal, such as an ADSL signal, is transmitted from an ADSL loop to an input of MDF 22. MDF 22 transmits the mixed voice/data signal to a voice/data port of splitter unit 24. Splitter unit 24 separates a mixed voice/data signal (e.g., ADSL signal) into a data signal and a voice signal. It is noted that the voice signal may also contain billing tone signal content.

The data signal is transmitted from splitter unit 24 to a digital

multiplexer device 26, such as a DSLAM device. In a configuration in which a digital cross connect unit 25 is employed, the digital signal communicated from the splitter unit 24 may be routed to the DSLAM 26 via the cross connect unit 25. An exemplary digital cross connect unit is disclosed in commonly owned U.S. Serial No 09/461,529, filed 14 December 1999 under attorney docket no. 245.00080101, which is hereby incorporated by reference in its entirety.

It is noted that splitter unit 24, in addition to providing for lowpass filtering of the mixed voice/data signal for voiceband applications, may further provide for bandpass filtering of the mixed voice/data signal for tone-based applications (e.g., billing or metering tones). In one embodiment, the splitter unit 24 provides for both lowpass and bandpass filtering within the same topology. An exemplary splitter unit employing both lowpass and bandpass filtering is disclosed in commonly owned U.S. Serial No 09/521,589, filed 09 March 2000 under attorney docket no. 245.00090101, which is hereby incorporated by reference in its entirety.

The operation of a splitter unit which employs a controllable bypass device and methodology according to the present invention will now be described within the context of various embodiments illustrated in the figures. It is assumed for purposes of this illustrative example that the mixed voice/data signal communicated to the splitter unit 24 conforms to an ADSL standard. It is understood that the splitter unit 24 shown in Figs. 1 and 3 may be implemented as circuitry supported on a card or module, as a component of a digital cross-connect system, as a stand-alone unit, or as a distributed device such that some of the bypass circuitry is provided in the splitter unit 24 and some of the bypass circuitry is provided external to the splitter unit 24 (e.g., within the cross-connect unit 25, DSLAM 26, or other unit).

An ADSL signal is applied to an input interface 15 of the splitter unit 24. The input interface 15 typically includes impedance matching circuitry to provide for proper impedance matching between the ADSL signal

connection and the splitter unit circuitry. The input interface 15 may be implemented to provide for matching of fixed or complex connection impedances. For example, the input interface 15 may be implemented to accommodate a complex input impedance conforming to a European harmonized impedance reference specification.

The ADSL signal received by the input interface 15 of the splitter unit 24 is communicated to a highpass filter 32 which operates on the ADSL signal to pass only the databand signal content of the ADSL signal. The databand signal content is communicated from the highpass filter 32 to an data interface 17. The data interface 17 provides access to the data signal processed by the highpass filter 32. The data interface 17 may include impedance matching circuitry to provide for proper matching of fixed or complex impedances between the data interface 17 and a data line connection coupled thereto, such as a data line or connection to cross connect unit 25 and/or DSLAM 26.

The ADSL signal received by the input interface 15 is also communicated to a lowpass filter 30 of the splitter unit 24. The lowpass filter 30 passes ADSL signal content associated with a voiceband defined by ADSL signal frequencies of up to about 4 or 5 kHz (nominally about 4 kHz). In addition to lowpass filtering, the splitter unit 24 may provide a bandpass filtering response for processing billing or metering tones, which typically have a frequency falling between the voiceband and the databand (e.g., tone frequencies of 12 kHz, 16 kHz or 20 kHz).

Voiceband content extracted from the ADSL signal by the lowpass filter 30 is communicated to a voice interface 19 of the splitter unit 24. The voice interface 19 may include impedance matching circuitry to provide for proper matching of fixed or complex impedances between the voice interface 19 and a voice line connection coupled thereto.

Figure 2 illustrates several steps associated with a splitter unit bypass operation according to an embodiment of the present invention. A bypass procedure may be initiated 100 remotely or locally. For example, a

splitter/bypass operation as described herein may be controlled by use of a line test unit or other device responsive to control signals received from a remotely located control signal source. Exemplary testing systems and methodologies suitable for effecting remote test access and remote activation and control of a splitter/bypass operation of the present invention are disclosed in commonly owned U.S. Serial No 09/461,529, filed 14 December 1999 under attorney docket no. 245.00080101, U.S. Serial Nos. 09/219,269 and 09/218,810, filed concurrently on 23 December 1998 under attorney docket nos. 245.00030101 and 245.00050101, respectively, and U.S. Serial No. 09/327,060, filed June 7, 1999 under attorney docket no. 245.00030120, each of which is hereby incorporated herein by reference in its respective entirety.

Remote control activation and supervision of a bypass operation of the present invention allows a remotely located test technician to initiate, evaluate, and control a splitter bypass operation of the present invention. For example, a remotely situated technician may select a desired voice/data line or loop for testing, initiate a bypass operation in cooperation with the splitter unit, perform one or more full frequency spectrum line tests of the selected line/loop, and terminate the bypass/testing operation by transmission of a control signal or automatically by expiration of a bypass timer, thereby returning the selected line/loop to its normal service state.

The voiceband signal path, alternatively termed the voice line herein, is sensed 102 to determine whether a call is in progress. If a call is currently in progress 104, the bypass operation is suspended or terminated 106. For example, the bypass circuitry may be deactivated or transitioned to a dormant state until the in-progress call is completed.

If the voice line of interest in not presently supporting a call 104, the bypass circuitry, typically integrated within or coupled to the splitter unit, is activated 108. Upon successfully completing the bypass operation, the voice line of interest is made accessible 110 to the testing device (e.g., an MLT unit).

The voice line under test is monitored during the line testing operation to detect a change in status (e.g., a change in On/Off hook status). The selected voice line is subjected to line testing 114 preferably for a predetermined duration of time or until a call is initiated on the selected voice line. If, during line testing, a call is initiated 112, which is typically detected by sensing a change in On/Off hook status, the bypass circuitry is deactivated 116 and normal voice service on the line is provided 118. In this manner, lifeline voiceband support is fully maintained prior to, during, and after a bypass operation of the present invention is performed.

Figure 3 is a block diagram of various components and interconnections for effecting a splitter bypass operation according to an embodiment of the present invention. According to this embodiment, the block diagram of Fig. 3 represents a more detailed depiction of the splitter unit 24 shown in Fig. 1. It is understood that the relay bypass architecture and/or functionality illustrated in Fig. 3 is not limited to use and implementation with respect to a splitter unit, such as a POTS splitter unit. For example, one skilled in the art will appreciate that the relay bypass architecture and/or functionality depicted in Fig. 3 may be employed in multiple frequency band splitting devices designed for ISDN and HPNA (Home Phone Network Adapter) architectures.

The splitter unit 24 shown in Fig. 3 incorporates a lowpass filter 30 and a highpass filter 32 which are commonly employed in many splitter unit implementations (e.g., a POTS splitter). The functions of the lowpass and highpass filters 30 and 32 are generally equivalent to those discussed above with respect to Fig. 1. It can be seen that the highpass filter 32 includes a DC blocking capacitor 31, which is generally representative of the DC and/or low frequency blocking response of the filtering circuitry employed in the highpass filter 32.

As was discussed hereinabove, the response of the in-line highpass filter 32 blocks DC test signals and significantly degrades low frequency test signals communicated on the high frequency/data signal path 38 within the

splitter unit 24. As such, the presence of the highpass filter 32 or other DC blocking elements within the high frequency/data signal path 38 prevents full bandwidth testing of the line. For example, full wideband MLT functional testing of an ADSL loop would not be fully effective in a splitter implementation in which the DC blocking response of the filtering elements on the high frequency/data signal path 38 remains undisturbed.

An important aspect of a splitter/bypass architecture of the present invention concerns the effective bypassing of the DC/low frequency blocking response of the high frequency/data signal path filtering elements. In the embodiment depicted in Fig. 3, a relay 57 is shown coupled across highpass filter 32 which incorporates DC blocking capacitor 31. In this configuration, relay 57 represents a normally open (N/O) relay which does not interfere (i.e., non-intrusive) with the communication of signals along the high frequency/data signal path 38. In an activated state, however, relay 57 closes to effectively bypass the DC/low frequency blocking elements 31 of the highpass filter 32. As such, the full frequency spectrum of the high frequency/data signal path 38 is made available for testing equipment upon activation of relay 57. Upon deactivation, relay 57 transitions to its normally open state.

The bypass circuitry of the splitter unit 24 includes a second relay 60, which in this configuration represents a normally closed relay. Relay 60 operates to disconnect and reconnect the voice line 40 at a location prior to the lowpass filter 30 and voice switch 28. Opening the voice line 40 at this location by relay 60 effectively removes the appearance of impedances introduced on voice line 40 by the lowpass filter 30 and voice switch 28.

The bypass circuitry of the splitter unit 24 includes a third relay 58, which in this configuration represents a normally closed relay. Relay 58 operates to disconnect and reconnect a power circuit 49 from a line which provides a source of power thereto. Relay 58 also operates to remove impedances associated with the bypass circuitry (e.g., bandpass filter 54, FLL 56, control circuit 50) from the test path. In the configuration shown in

Fig. 3, the bypass circuitry of the splitter unit 24 may be considered "passive" device, in that the splitter unit 24 need not be equipped with its own power source. In one embodiment, the splitter unit 24 is not equipped with an active power source and does not require power to perform its voice/data signal splitting function.

Rather, the bypass circuitry of the splitter unit 24 preferably derives power needed to implement a bypass operation from the line testing equipment or other source of external power, such as a cross-connect unit 25. The splitter unit 24 may also include a battery as part of the power circuit 49.

In an embodiment in which an external power source, such as the line testing equipment (e.g., MLT system 23) or cross-connect unit 25 for example, is available to the bypass circuitry, the power circuit 49 shown in Fig. 3 would not be required. In this configuration, the external power source provides power to the bypass circuitry for effecting bypass functions and for producing a detection current which is used to sense a change in On/Off hook status. Relay 58, in this case, operates to remove impedances associated with the bypass circuitry from the test path, and a separate power line (not shown) may be coupled to the control circuit 50 and relays 57, 58, and 60 to provide the requisite power to these components.

According to one embodiment, the power circuit 49 of the bypass/splitter unit 24 includes one or more charging capacitors. During a line testing operation, the tester, such as an MLT device, provides a voltage or current which charges the charging capacitor(s) of the power circuit 49 prior to, and, if needed, during, the line testing operation.

The power circuit 49 also provides a detection current to the loop subjected to evaluation. The detection current is used for accomplishing line usage sensing. A change in the detection current provided to a loop subjected to line testing typically indicates a change in On/Off hook status. Upon detecting such a change in the detection current, the bypass circuitry is deactivated to restore normal voice line service. The detection current

may be a current falling within the microamp range up to the milliamp range on a per loop basis.

The splitter unit 24 further includes a control circuit 50 which controls the bypass circuitry of the splitter unit 24. The control circuit 50 communicates control signals to each of relays 60, 51, and 58 to bypass the DC blocking capacitor 31 of the highpass filter 32 (via relay 57) and to decouple the voice line 40 from the lowpass filter 30 and voice switch 28 (via relay 60) according to a control sequence which provides for full frequency spectrum testing of the loop while guaranteeing full lifeline support.

A voice line sensing circuit 52, shown as on/off hook sensing circuitry 52 in Fig. 3, receives a signal from a voice line sensor 62 indicative of the usage state of voice line 40. The voice line sensor 62 senses the voice line to determine if a call is presently in progress or whether a call is being initiated. In one embodiment, the voice line sensor 62 includes a current detector and a voltage detector. The voice line sensor 62 senses the presence of a loop current and/or a low voltage (e.g., off-hook voltage) developed on the voice line 40. The control circuit 50 receives a signal from the voice line sensing circuit 52 indicative of the usage state of the voice line 40 as detected by the voice line sensor 62. For example, if a loop current and/or a low voltage indicative of line usage is sensed, the voice line sensing circuit 52 communicates a deactivation signal to the control circuit 50, which in turn, deactivates the bypass procedure.

Also coupled to the control circuit 50 is a frequency locked loop (FLL) circuit 56. The FLL circuit 56 indicates a valid start condition for activating the bypass circuitry. The FLL circuit 56 locks onto a modulated signal presented by the tester/test head. The modulated signal is used to trigger the activation sequence of the bypass circuitry. In one embodiment, the modulated signal may be generated as a sinewave having a frequency of 25 Hz or lower. A bandpass filter 54 is coupled to the FLL circuit 56 and selectively blocks false trigger signals that might result from receipt of a high frequency/data signal.

According to one embodiment of a bypass control sequence, as is depicted in Figs. 4 and 5, a bypass procedure is initiated 150 with relays 60, 57, and 58 in their respective normal states, namely, normally closed, normally open, and normally closed, respectively. The high frequency or data signal (e.g., DSL signal) is interrupted 152 by some external means in order to remove all frequency components from the data spectrum. A "chirped" high frequency signal or other predetermined DC or AC stimulus signal may be presented to the now quiet loop by the tester/test head in order to determine if any loop impairments exist or to determine other conditions or characteristics of the loop. If desired, the tester/test head may generate a status message indicating to a user or equipment couple to the high frequency signal path that testing is currently being conducted on the subject line.

An external test-head, such as the xDSL test head 27 shown in Fig. 1, MLT test system 23, or other testing device, presents a voltage or current which charges 154 the charging capacitor of power circuit 49 or otherwise provides power to the bypass circuitry. In one embodiment, the charging capacitor provides the dual function of providing power for the bypass circuitry and operating as part of a timer circuit 47. In this configuration, the charge decay rate of the charge capacitor dictates the duration of time in which the bypass state of the bypass/splitter unit 24 is maintained, and thus the time allotted for line testing. It is understood that other timer circuits and devices may be employed, such as a PLL (phase locked-loop), one-shot, or monostable multivibrator circuit.

For example, the duration of "on" time of the bypass circuitry may be established by the amount of time required for the voltage of the charge capacitor to decay from a first voltage threshold (e.g., maximum capacitor voltage) to a timeout voltage threshold (minimum capacitor voltage). The duration of "on" time typically falls in the range of several seconds, such as between 4 and 30 seconds, but may be as long as a minute or two. The "on" time determined by the timer circuit 47 may be fixed or variable/

programmable according to a particular implementation. Those skilled in the art will appreciate that other configurations of the power circuit 49 and timer circuit 47 fall within the scope of the invention, and that such configurations may vary from those depicted in Fig. 3 and described herein.

The test device that charges 154 the bypass circuitry may further generate a signal that activates the FLL circuit 56. Once the FLL circuit 56 indicates 156 a valid start condition, the voice line sensor 62 and sensing circuit 52 cooperate to evaluate the state of the voice line 40. If a call is in progress 158, the bypass procedure is terminated or suspended 160. As such, the bypass circuitry remains in a dormant state. If no call is in progress 158, the duration timer circuit 47 is activated 162.

The control circuit 50 transmits a control signal to relay 60 over line 55 causing normally closed relay 60 to activate (i.e., to open). Activation of relay 60 by the control circuit 50 results in disconnecting 164 the POTS voiceband circuitry (e.g., lowpass filter 30 and downstream voice switch 28 via MDF 22) from the voice line 40.

After relay 60 is opened, the control circuit 50 transmits a control signal to normally open relay 57 via line 51 causing relay 57 to close.. Closing relay 57 in this manner effectively provides 166 for a shunt or bypass around the DC blocking capacitor 31 or other DC/low frequency filtering elements of the highpass filter 32. The control circuit 50 also transmits a control signal to normally closed relay 58, which opens the power-feed to the power circuit 49, thereby removing 170 power from the bypass circuitry. At this stage, the bypass circuitry has reached its enabled state.

Testing of the line is performed 172. If a call is initiated during line testing 174, as detected by the voice line sensor 62 and sensing circuit 52, the control circuit 50 transmits control signals to relay 60 so as to deactivate 176 the bypass of the voice line 40. The POTS voiceband circuitry is thus reconnected to the voice line 40 thereby enabling full lifeline usage 184 of the voice line 40.

Assuming no call is initiated during the line testing operation 174, line testing continues until the duration of on time as determined by the timer circuit 47 has expired 180. Upon expiration of the duration of time allotted for line testing, the control circuit 50 transmits control signals to relays 60, 57, and 58 so as to return these relays to their normal states, thereby deactivating 182 the bypass circuitry. Normal line service is thus resumed 184.

The foregoing description of the various embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. For example, the bypass circuitry of the present invention may be provided in a device other than a multiband signal splitting unit 24. The bypass circuitry may be distributed among two or more devices and need not be integral to a single splitter unit 24.

In the embodiment shown in Fig. 6, for example, the cross-connect unit 25 effectively incorporates the highpass filter 32 which includes the DC blocking capacitor 31 as part of its circuitry. In this case, the splitter unit 24 need not include an otherwise redundant HPF circuit 32. Relay 57, which provides for controlled bypassing of DC blocking capacitor 31, is provided within the cross-connect unit 25, rather than in splitter unit 24. In this case, relay 57 may represent a controllable relay within the field of relays provided in the cross-connect unit 25, rather than a relay separate from the field of relays. As may be the case in other embodiments described herein where impendances associated with LPF 30 can be tolerated during line/loop testing, the LPF 30 may remain operative in the loop subjected to testing.

Moreover, the advantages and features of the present invention may be applied in a wide variety of electrical conductor-based or optical-based communications systems, such as those employing single-mode or multiple-mode serial or parallel optical links.

It is intended that the scope of the invention be defined not by this detailed description, but rather by the claims appended hereto.

CLAIMS

What is claimed is:

1. A method of bypassing circuitry of a voice/data splitting unit connectable to a communications connection comprising a voice line and a data line, the method comprising:

during non-usage of the voice line, bypassing a DC and/or low frequency filtering element of the splitter unit coupled to the data line and decoupling the voice line from the splitter unit to provide full frequency spectrum test access to the voice and data lines; and

recoupling the voice line to the splitter unit in response to usage of the voice line.

2. The method of claim 1, further comprising interrupting data signal transmission on the data line and using a test signal to detect a condition or characteristic of the data line and/or at least a portion of the voice line.

3. The method of claim 1, further comprising sensing the voice line to determine usage and non-usage of the voice line.

4. The method of claim 3, wherein sensing the voice line comprises sensing a parameter of current, voltage, or magnetism with respect to the voice line.

5. The method of claim 1, wherein the voice line is recoupled to the splitter unit in response to usage of the voice line or expiration of a predetermined duration of time.

6. The method of claim 1, wherein bypassing the DC and/or low frequency filtering element further comprises establishing connectivity

around the DC and/or low frequency filtering element.

7. The method of claim 1, wherein bypassing the DC and/or low frequency filtering element further comprises activating a controllable relay that establishes connectivity around the DC and/or low frequency filtering element.

8. The method of claim 1, wherein decoupling the voice line further comprises removing impedances associated with the splitter unit and/or voice line circuitry from the voice line.

9. The method of claim 1, wherein decoupling the voice line further comprises activating a controllable relay to decouple the voice line from the splitter unit.

10. The method of claim 1, wherein recoupling the voice line further comprises activating a controllable relay to recouple the voice line with the splitter unit.

11. The method of claim 1, further comprising deriving power from a power source prior to initiating the bypassing and recoupling operations.

12. The method of claim 11, further comprising removing the power from the power source in response to initiating the bypassing and recoupling operations, wherein the voice line is recoupled to the splitter unit and the DC and/or low frequency filtering element of the splitter unit is recoupled to the data line in response to depletion of the derived power to a preestablished threshold.

13. The method of claim 1, further comprising testing one or both of the voice and data lines during non-usage of the voice line and after

completion of the bypassing operation.

14. An apparatus for splitting voice and data signal content of a mixed voice/data signal transmitted over a communications connection comprising a voice line and a data line, the apparatus comprising:

a splitter unit having a voice/data port, a voice port connectable to the voice line, and a data port connectable to the data line, the splitter unit further comprising a DC and/or low frequency filtering element coupled to the data line, and a lowpass filter coupled to the voice line; and

a bypass device coupled to the voice line and the data line, the bypass device comprising:

a data line bypass circuit for controllably bypassing and recoupling the DC and/or low frequency filtering element with respect to the data line; and

a voice line bypass circuit for controllably decoupling and recoupling the voice line with respect to a voice line location between the voice/data port of the splitter unit and the lowpass filter.

15. The apparatus of claim 14, wherein the bypass device further comprises a controller coupled to the respective data and voice line bypass circuits, the controller controlling the data and voice line bypass circuits in response to usage of the voice line.

16. The apparatus of claim 14, wherein the bypass device further comprises a voice line sensor that senses usage of the voice line.

17. The apparatus of claim 16, wherein the voice line sensor comprises one or more of a current detector, a voltage detector, a magnetic sensor, and/or an electromagnetic sensor.

18. The apparatus of claim 16, wherein the bypass device further

comprises a controller coupled to the voice line sensor and the respective data and voice line bypass circuits, the controller controlling the data and voice line bypass circuits in response to usage of the voice line as determined by the voice line sensor.

19. The apparatus of claim 16, wherein the bypass device further comprises a controller coupled to the voice line sensor and the respective data and voice line bypass circuits, the controller, in response to non-usage of the voice line as detected by the voice line sensor, bypassing the DC and/or low frequency filtering element coupled to the data line and decoupling the voice line at the voice line location between the voice/data port of the splitter unit and the lowpass filter, and, in response to usage of the voice line as detected by the voice line sensor, recoupling the DC and/or low frequency filtering element to the data line and recoupling the voice line to the voice line location between the voice/data port of the splitter unit and the lowpass filter.

20. The apparatus of claim 14, wherein the data line bypass circuit comprises a controllable relay coupled around the DC and/or low frequency filtering element coupled to the data line.

21. The apparatus of claim 14, wherein the voice line bypass circuit comprises a controllable relay that decouples and recouples the voice line to the voice line location between the voice/data port of the splitter unit and the lowpass filter.

22. The apparatus of claim 14, wherein the bypass device further comprises a timing circuit that determines a duration of time during which the data line bypass circuit bypasses the DC and/or low frequency filtering element coupled to the data line and during which the voice line bypass circuit decouples the voice line from the voice line location between the

voice/data port of the splitter unit and the lowpass filter.

23. The apparatus of claim 14, wherein the bypass device further comprises a power circuit for powering the data and voice line bypass circuits.

24. The apparatus of claim 23, wherein the power circuit derives power from a source external to the splitter unit or the bypass device.

25. The apparatus of claim 23, wherein the power circuit derives power from a line testing device.

26. The apparatus of claim 23, wherein the power circuit comprises a timing circuit, the timing circuit determining a duration of time during which the data line bypass circuit bypasses the DC and/or low frequency filtering element coupled to the data line and during which the voice line bypass circuit decouples the voice line from the voice line location between the voice/data port of the splitter unit and the lowpass filter.

27. The apparatus of claim 23, further comprising a relay coupled between the bypass device and the power source, the relay controllable to decouple the power source from the bypass device and to remove impedances associated with the bypass device from a test path.

28. The apparatus of claim 14, wherein the bypass device is integral with the splitter unit.

29. The apparatus of claim 14, wherein at least a portion of the bypass device is external to the splitter unit.

30. The apparatus of claim 14, wherein the bypass device is

responsive to a signal received from a device external to the splitter unit or the bypass device.

31. The apparatus of claim 14, wherein the bypass device is responsive to a signal received from a tester unit.

32. An apparatus for splitting a first band of signal frequencies and a second band of signal frequencies of a multiband signal transmitted over a communications connection comprising a first signal line and a second signal line, the apparatus comprising:

a splitter unit having a voice/data port, a first port connectable to the first signal line, and a second port connectable to the second signal line, the splitter unit further comprising a first filtering element coupled to the first signal line, and a second filtering element coupled to the second signal line that degrades at least a portion of the frequency spectrum associated with the second band of signal frequencies; and

a bypass device coupled to the first signal line and the second signal line, the bypass device comprising:

a first bypass circuit for controllably decoupling and recoupling the first signal line; and

a second bypass circuit for controllably bypassing and recoupling the second filtering element with respect to the second signal line.

33. The apparatus of claim 32, wherein the second filtering element comprises a DC and/or low frequency degrading element and the first filtering element comprises a lowpass filter element.

34. The apparatus of claim 32, wherein the bypass device further comprises a controller coupled to the respective first and second bypass

circuits, the controller controlling the first and second bypass circuits in response to usage of the first signal line.

35. The apparatus of claim 32, wherein the bypass device further comprises a sensor that senses usage of the first signal line.

36. The apparatus of claim 35, wherein the sensor comprises one or more of a current detector, a voltage detector, a magnetic sensor, and/or an electromagnetic sensor.

37. The apparatus of claim 35, wherein the bypass device further comprises a controller coupled to the sensor and the respective first and second bypass circuits, the controller controlling the first and second bypass circuits in response to usage of the first signal line as determined by the sensor.

38. The apparatus of claim 35, wherein the bypass device further comprises a controller coupled to the sensor and the respective first and second bypass circuits, the controller, in response to non-usage of the first signal line as detected by the sensor, bypassing the second filtering element coupled to the second signal line and decoupling the first signal line at the first signal line location between the voice/data port of the splitter unit and the first filtering element, and, in response usage of the first signal line as detected by the sensor, recoupling the second filtering element to the second signal line and recoupling the first signal line to the first signal line location between the voice/data port of the splitter unit and the first filtering element.

39. The apparatus of claim 32, wherein the second bypass circuit comprises a controllable relay coupled around the second filtering element coupled to the second signal line.

40. The apparatus of claim 32, wherein the first bypass circuit comprises a controllable relay that controllably decouples and recouples the first signal line with respect to the first signal line location between the voice/data port of the splitter unit and the first filtering element.

41. The apparatus of claim 32, wherein the bypass device further comprises a timing circuit that determines a duration of time during which the second bypass circuit bypasses the second filtering element coupled to the second signal line and during which the first bypass circuit decouples the first signal line from the first signal line location between the voice/data port of the splitter unit and the first filtering element.

42. The apparatus of claim 32, wherein the bypass device further comprises a power circuit for powering the first and second bypass circuits.

43. The apparatus of claim 42, wherein the power circuit derives power from a source external to the splitter unit or the bypass device.

44. The apparatus of claim 42, wherein the power circuit derives power from a line testing device.

45. The apparatus of claim 42, wherein the power circuit comprises a timing circuit, the timing circuit determining a duration of time during which the second bypass circuit bypasses the second filtering element coupled to the second signal line and during which the first bypass circuit decouples the first signal line from the first signal line location between the voice/data port of the splitter unit and the first filtering element.

46. A method of splitting a first band of signal frequencies and a second band of signal frequencies of a multiband signal transmitted over a

communications connection comprising a first signal line and a second signal line, the method comprising:

during non-usage of the first signal line, disabling DC and/or low frequency filtering of the second signal line and decoupling the first signal line from line impedances to provide test access to the first and second signal lines; and

recoupling the first signal line to the line impendances in response to usage of the first line.

47. The method of claim 46, further comprising interrupting signal transmission on the second signal line and using a test signal to detect a condition of the second signal line and/or at least a portion of the first signal line.

48. The method of claim 46, further comprising sensing the first signal line to determine usage and non-usage of the first signal line.

49. The method of claim 46, wherein the first signal line is recoupled to the line impedances in response to usage of the first signal line or expiration of a predetermined duration of time.

50. The method of claim 46, further comprising deriving power from a power source prior to initiating the disabling and recoupling operations.

51. The method of claim 46, further comprising testing one or both of the first and second signal lines during non-usage of the first signal line and after completion of the disabling operation.

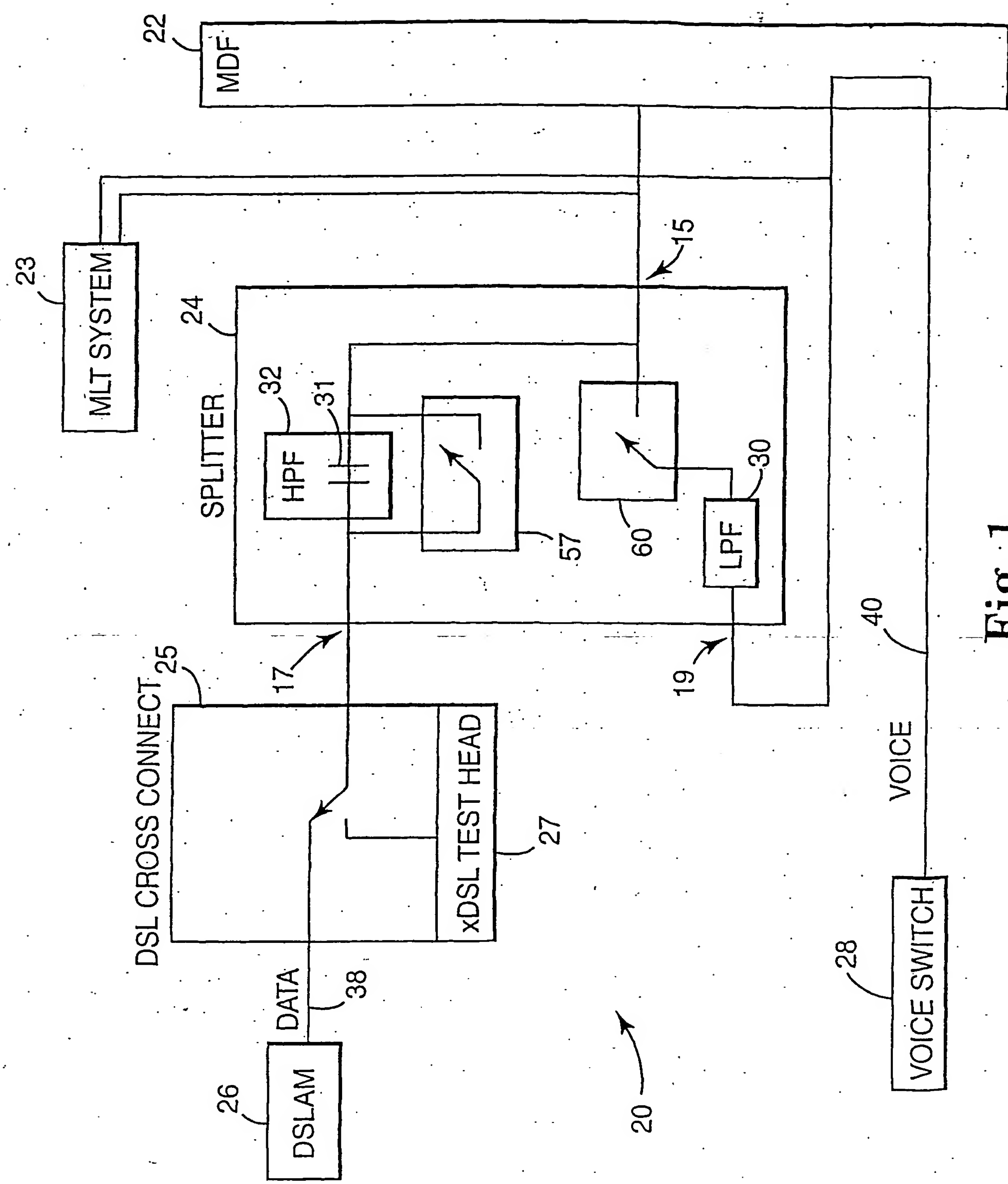
MDF
22
MLT SYSTEM
23
SPLITTER
24
15
HPF
32
31
57
60
LPF
30
DSL CROSS CONNECT
25
17
19
xDSL TEST HEAD
27
DATA
38
DSLAM
26
20
VOICE
40
VOICE SWITCH
28

Fig. 1

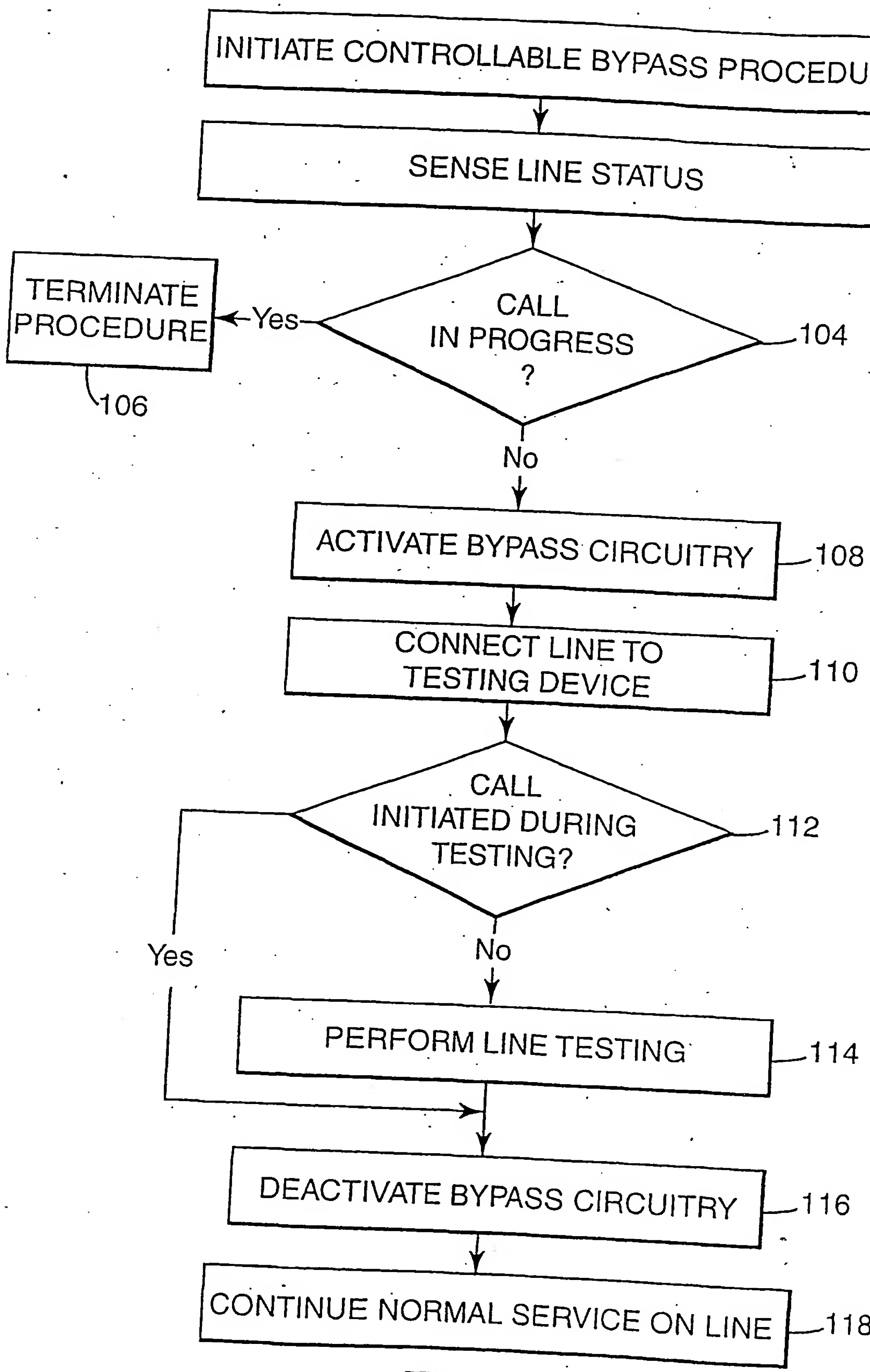
INITIATE CONTROLLABLE BYPASS PROCEDURE
100
SENSE LINE STATUS
102
CALL IN PROGRESS ?
104
Yes
TERMINATE PROCEDURE
106
No
ACTIVATE BYPASS CIRCUITRY
108
CONNECT LINE TO TESTING DEVICE
110
CALL INITIATED DURING TESTING?
112
Yes
No
PERFORM LINE TESTING
114
DEACTIVATE BYPASS CIRCUITRY
116
CONTINUE NORMAL SERVICE ON LINE
118

Fig. 2

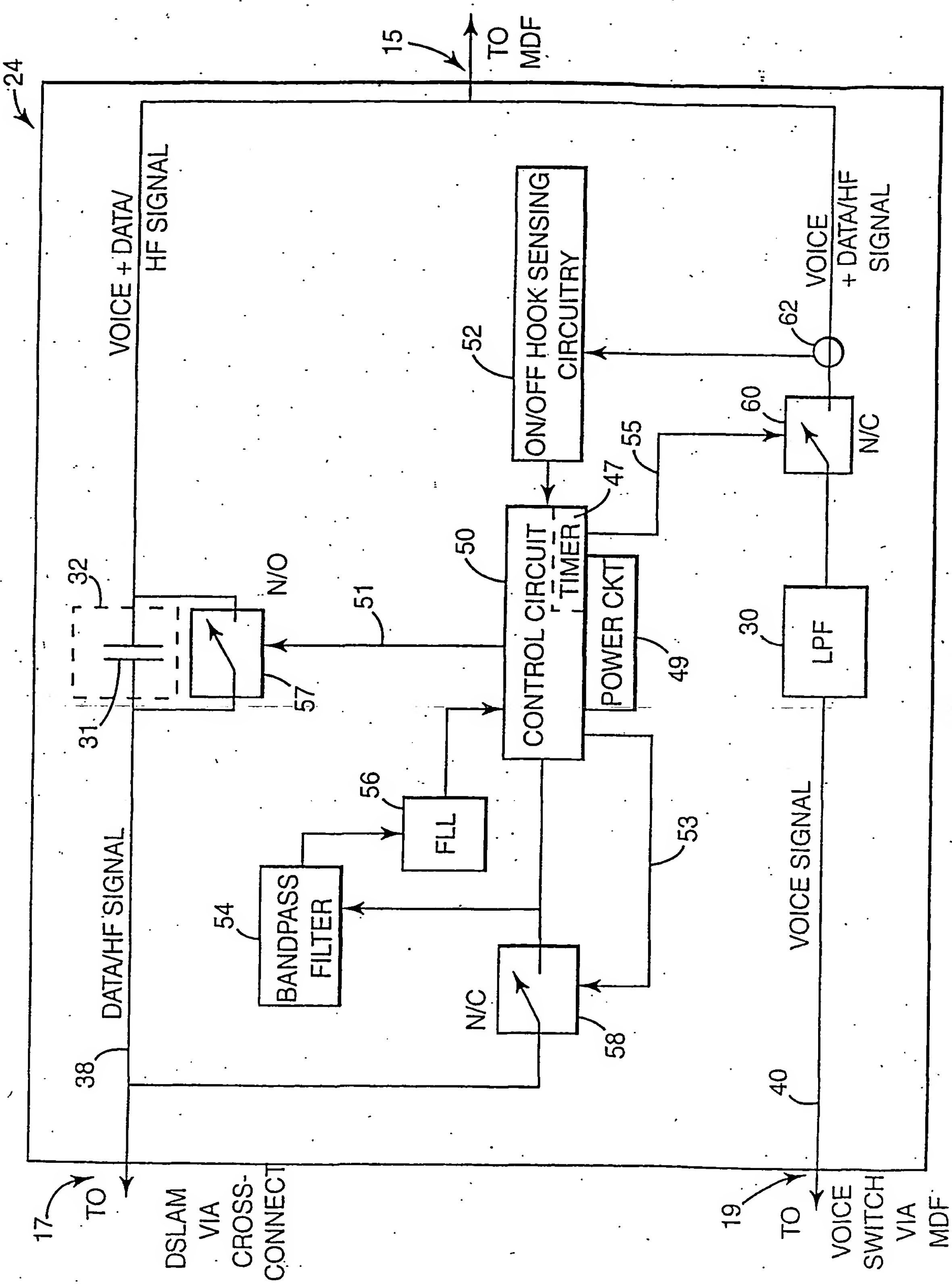
24
15
TO MDF
VOICE + DATA/ HF SIGNAL
VOICE + DATA/HF SIGNAL
52
ON/OFF HOOK SENSING CIRCUITRY
62
60
N/C
55
47
50
CONTROL CIRCUIT
TIMER
POWER CKT
49
32
31
N/O
51
57
30
LPF
56
FLL
54
BANDPASS FILTER
53
N/C
58
DATA/HF SIGNAL
VOICE SIGNAL
38
40
17
TO DSLAM VIA CROSS-CONNECT
19
TO VOICE SWITCH VIA MDF

Fig. 3

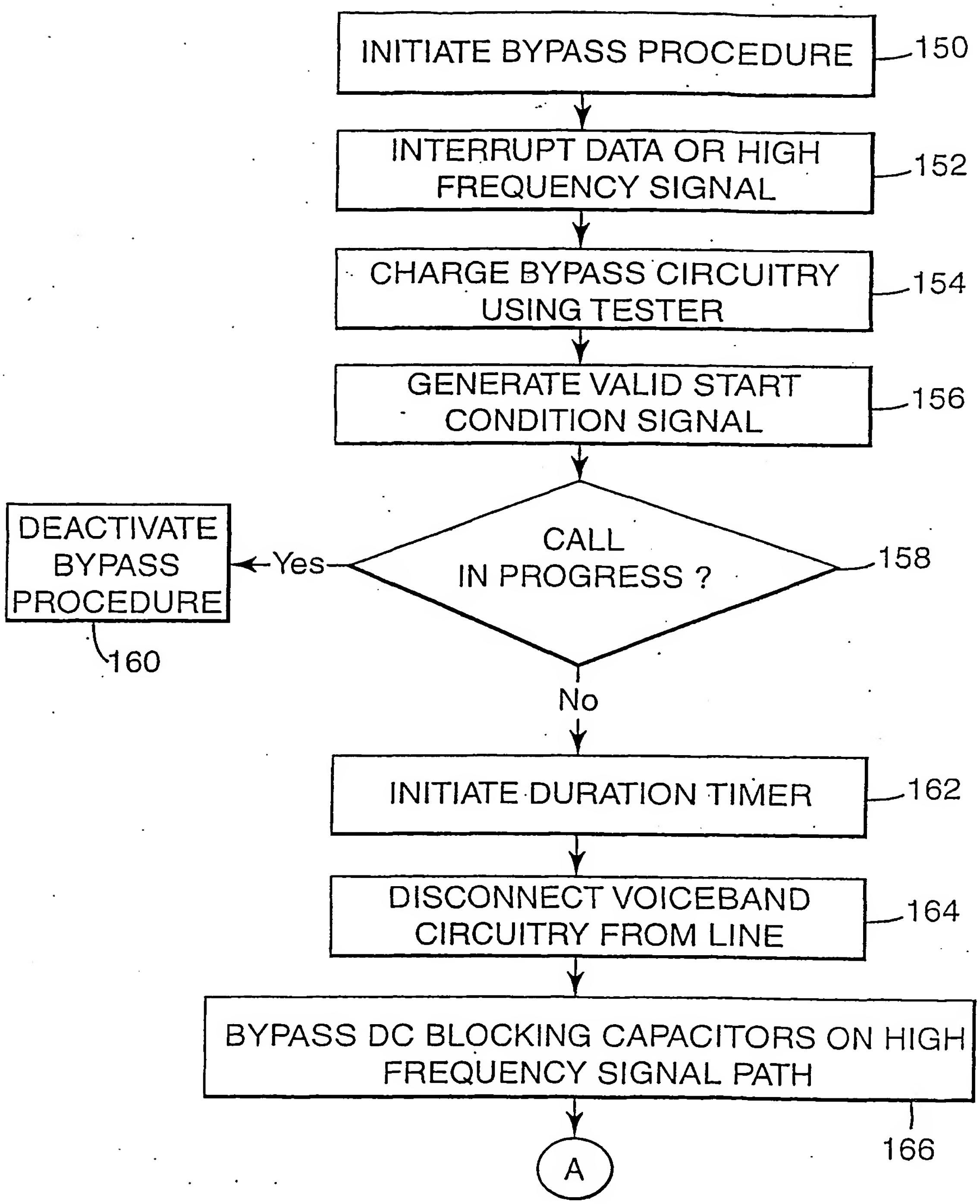
INITIATE BYPASS PROCEDURE
150
INTERRUPT DATA OR HIGH FREQUENCY SIGNAL
152
CHARGE BYPASS CIRCUITRY USING TESTER
154
GENERATE VALID START CONDITION SIGNAL
156
CALL IN PROGRESS ?
158
Yes
DEACTIVATE BYPASS PROCEDURE
160
No
INITIATE DURATION TIMER
162
DISCONNECT VOICEBAND CIRCUITRY FROM LINE
164
BYPASS DC BLOCKING CAPACITORS ON HIGH FREQUENCY SIGNAL PATH
166
A

Fig. 4

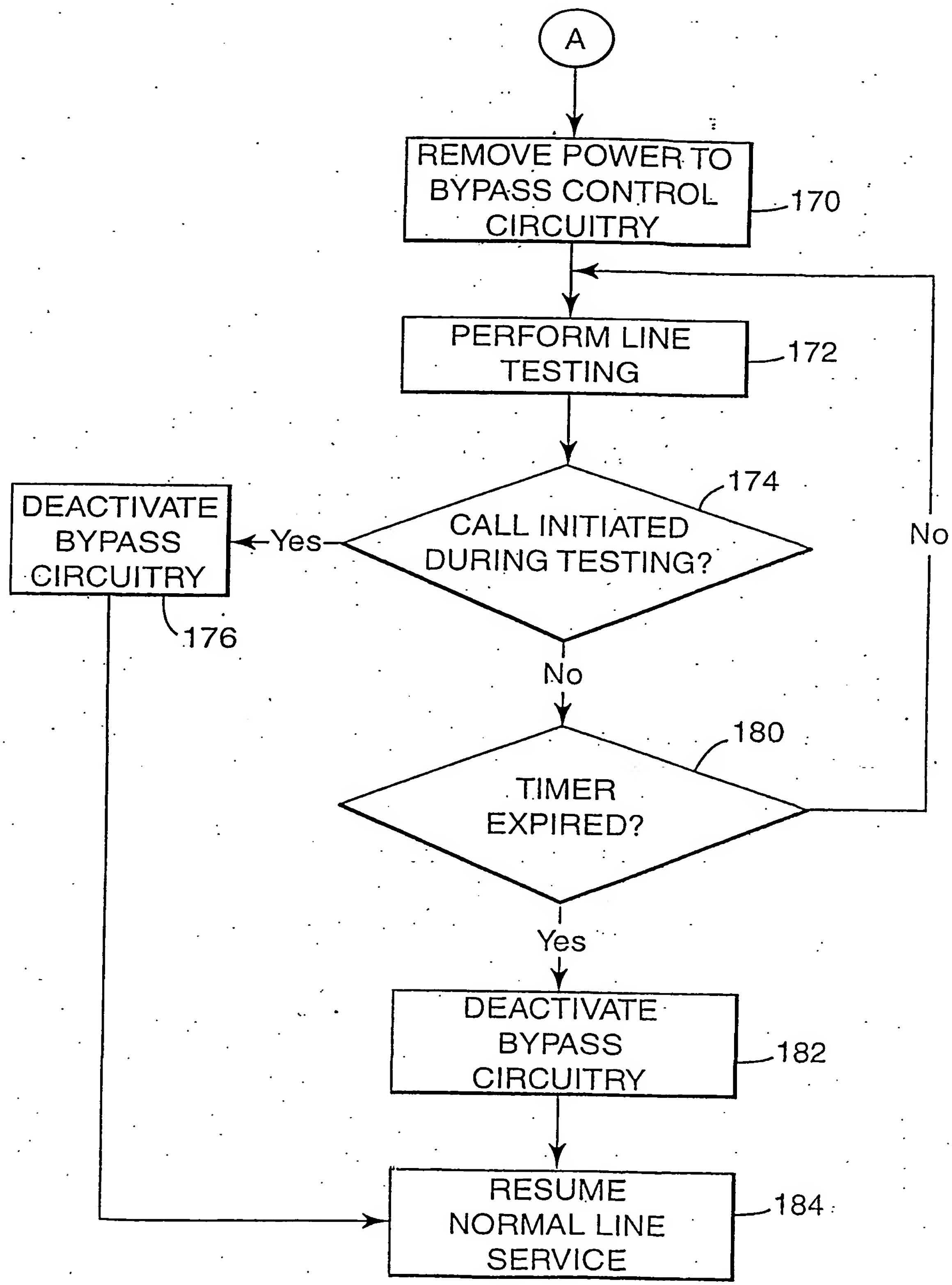
A
REMOVE POWER TO BYPASS CONTROL CIRCUITRY
170
PERFORM LINE TESTING
172
CALL INITIATED DURING TESTING?
174
Yes
DEACTIVATE BYPASS CIRCUITRY
176
No
TIMER EXPIRED?
180
No
Yes
DEACTIVATE BYPASS CIRCUITRY
182
RESUME NORMAL LINE SERVICE
184

Fig. 5

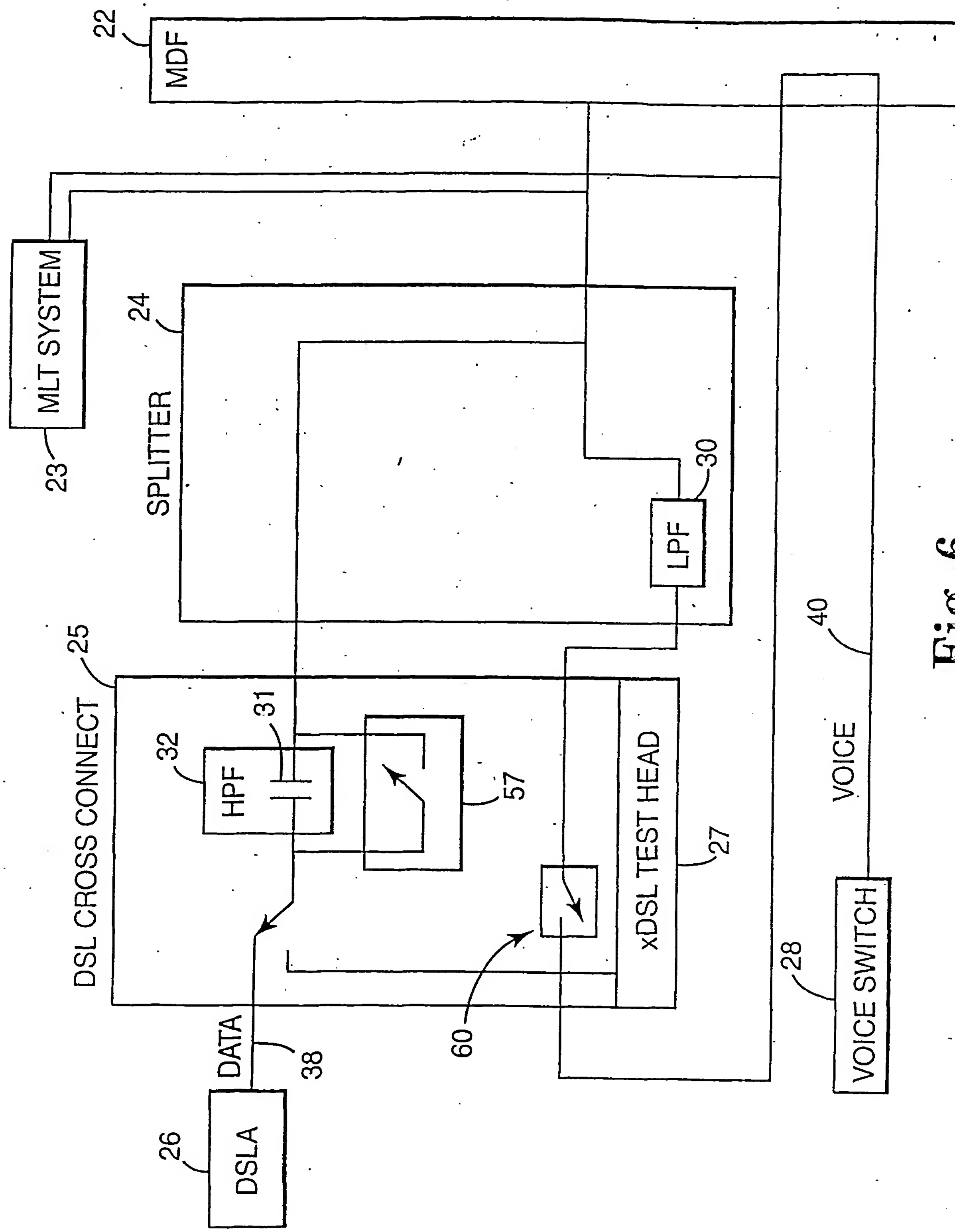
MDF
22
MLT SYSTEM
23
SPLITTER
24
LPF
30
DSL CROSS CONNECT
25
HPF
32
31
57
xDSL TEST HEAD
27
60
VOICE
40
VOICE SWITCH
28
DATA
38
DSLA
26

Fig. 6